U.S. DEPARTMENT OF ENERGY

Identifying Grid Needs and Evaluating Investment Options

Training for States on Distribution System and Distributed Energy Resources Planning

Presented by Samir Succar, ICF

Western Regional Training

January 24, 2024

Agenda

Mapping technologies to objectives

Planning objectives

Utility budgets

Investment prioritization

Cost-effectiveness methods

Actions and questions

Distribution System Planning Context

Baseline information on current state of distribution system

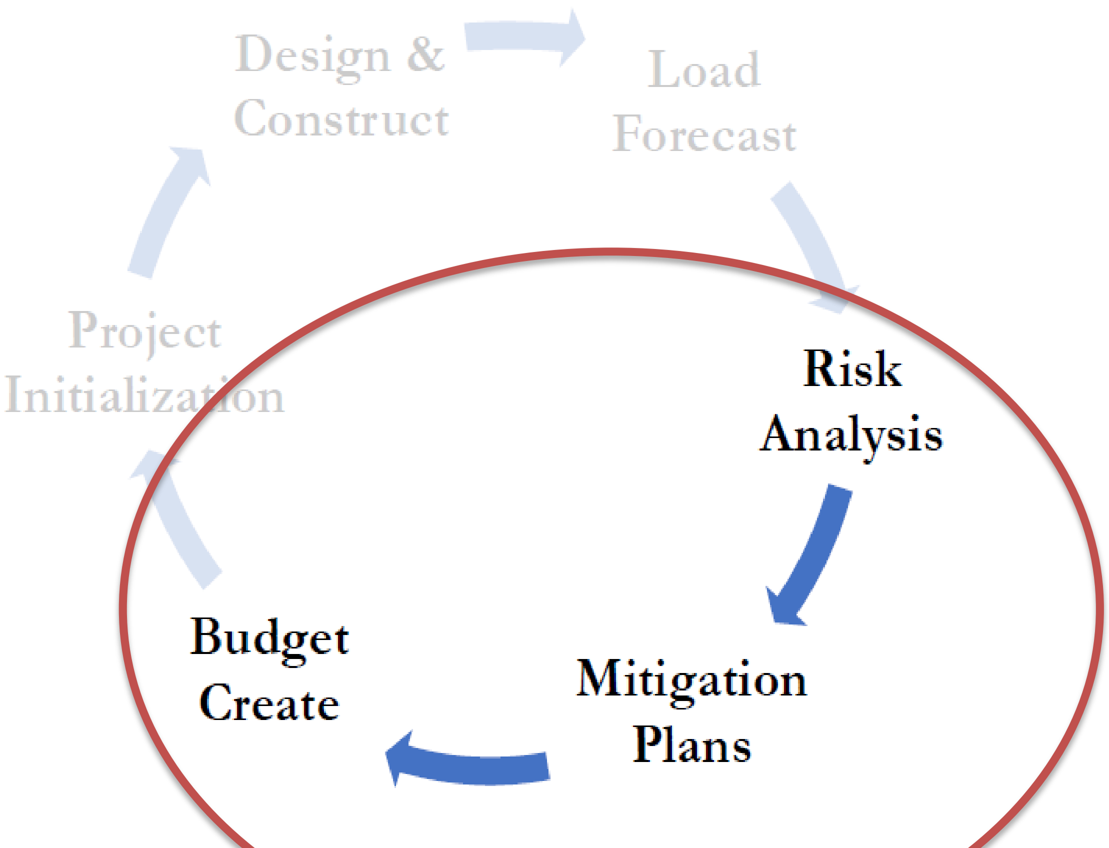
- Such as system statistics, reliability performance, equipment condition, historical spending by category

Description of planning process

- Load forecast – projected peak demand for feeders and substations
- Risk analysis for overloads and plans for mitigation
- Budget for planned capacity projects
  - Asset health analysis and system reinforcements
  - Upgrades needed for capacity, reliability, power quality
  - New systems and technologies
  - Ranking criteria (e.g., safety, reliability, compliance, financial)

Distribution operations

- Vegetation management
- Event management



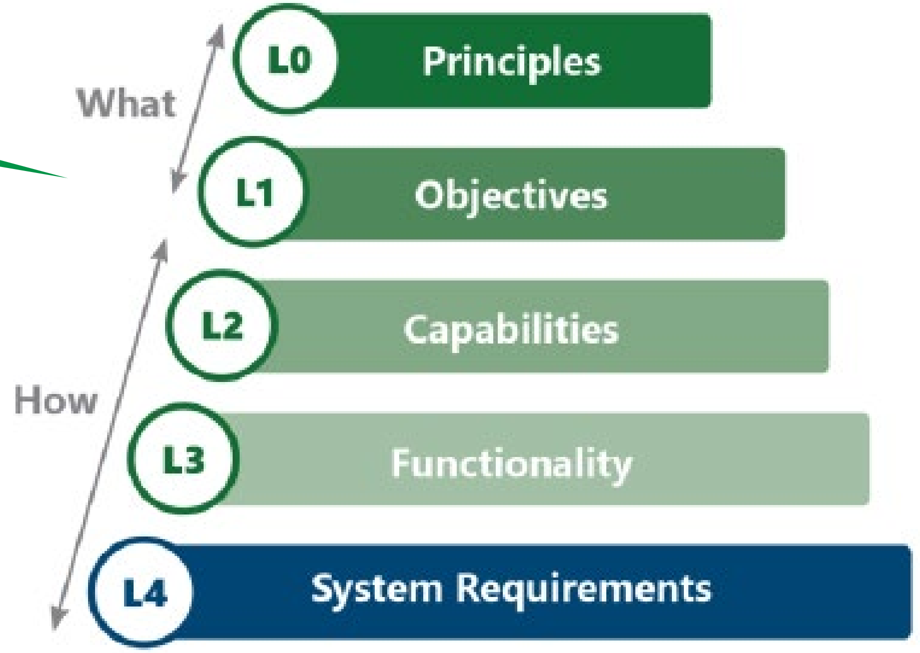
Source: Xcel Energy

Grid Modernization Strategy & Implementation Planning

Objective: An envisioned or desired result or outcome

?

System requirements: Technology solutions that can meet specific business and technical requirements



Source: *Modern Distribution Grid Guidebook, Strategy & Implementation Planning Guidebook*, Version 1.0 Final Draft, DOE Office of Electricity, June 2020; [Modern-Distribution-Grid_Volume_IV_v1_0_draft.pdf (pnnl.gov)]

Mapping Technologies to Objectives: **Reliability**

Objective	Capability	Function	Technology
Reliability improvement by reducing customer unplanned outage durations Achieve 2nd quartile CAIDI performance by 2025	Improve outage identification and customer service restoration	Fault Identification Fault Location Fault Isolation Service Restoration	Fault Current Indicators Outage Notification from Meters Outage Management System Geospatial Information System Distribution Management System and/or SCADA Automated Switches Work Management System

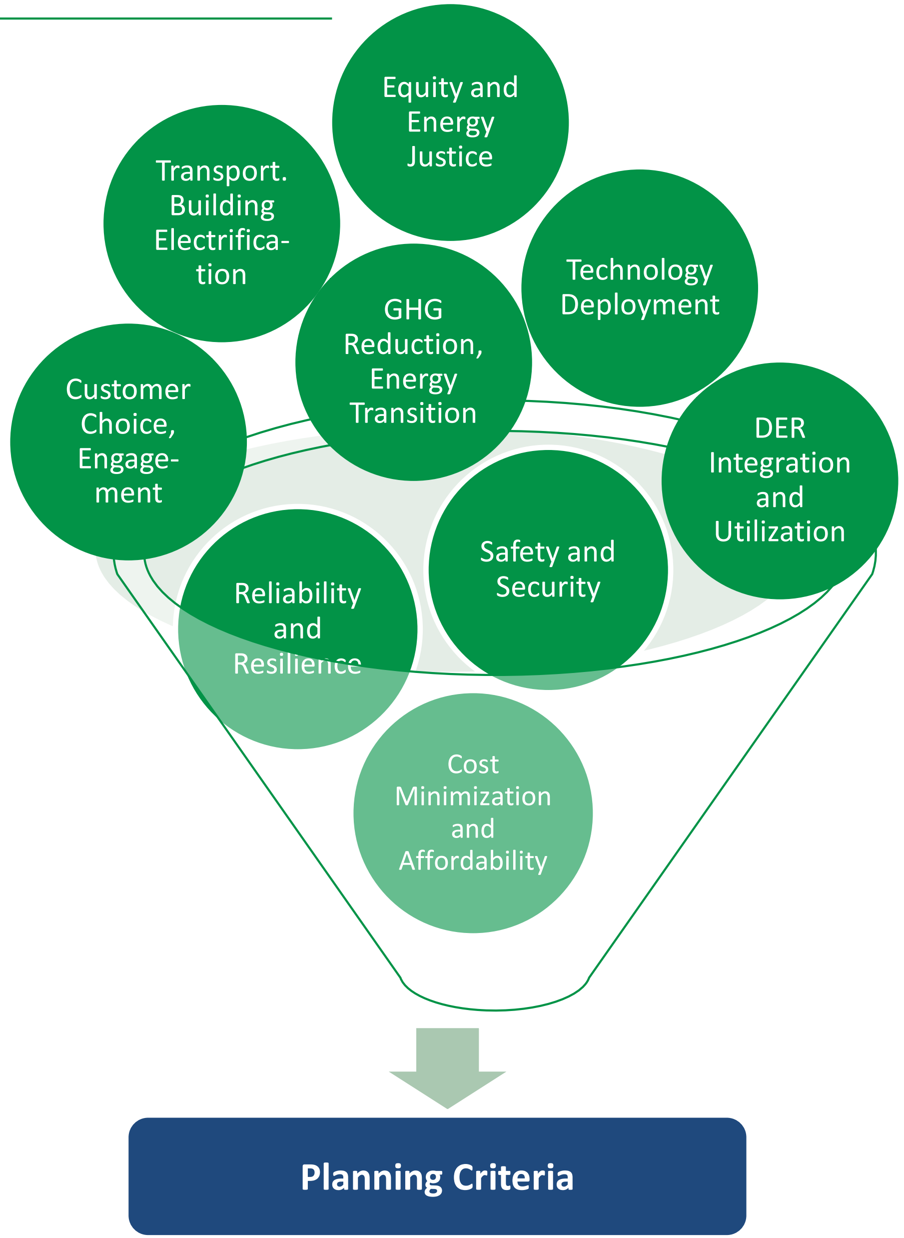
Source: *Modern Distribution Grid, Volume I: Customer and State Policy Driven Functionality, DOE, 2017;*
https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid_Volume-I_v1_1.pdf

Mapping Technologies to Objectives: **Customer Choice**

Objective	Capability	Function	Technology
Enable customer choice by providing information to support customer decisions	Provide online customer access to relevant & timely information by 2020 for small business & residential customers	Remote meter data collection & verification Customer data management Energy management & DER purchase analysis	Customer portal Customer analytic tools Green Button Time interval metering Meter Data Management System Customer information system Data warehouse Meter communications

Source: *Modern Distribution Grid, Volume I: Customer and State Policy Driven Functionality, DOE, 2017;*
https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid_Volume-I_v1_1.pdf

Translating Objectives into Criteria



Objectives: An envisioned or desired result or outcome

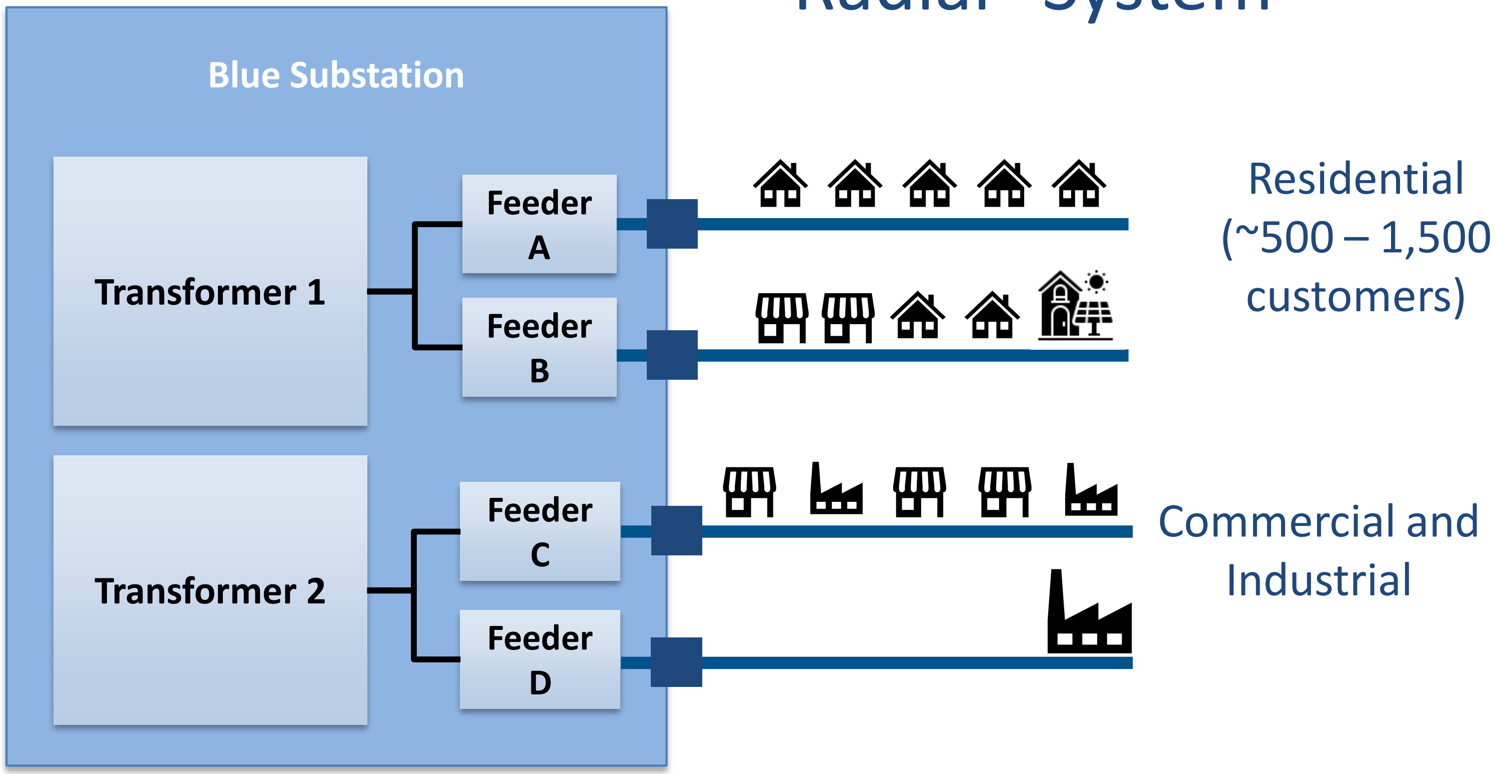
Criteria: Principles or standards by which system risks or solutions may be evaluated or prioritized

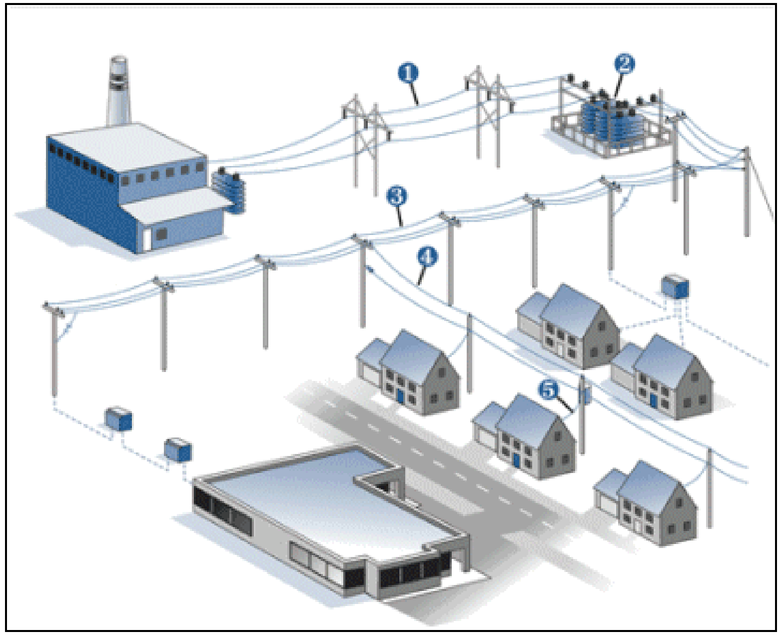
Planning for Electric Capacity

Normal Operations

Safety Reliability

"Radial" System





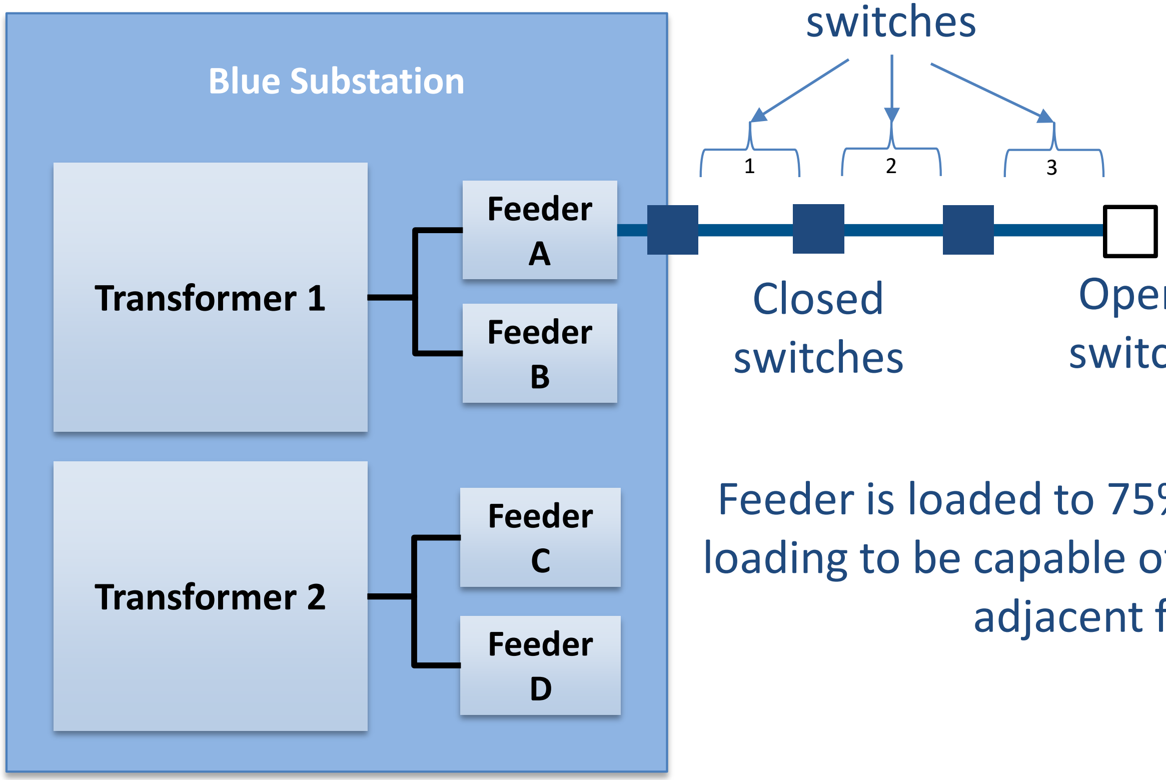
Credit: Ameren
https://www2.ameren.com/common/DistributionSystem.aspx

DER is analyzed for system normal configuration

Planning for Capacity

System Flexibility

Safety Reliability



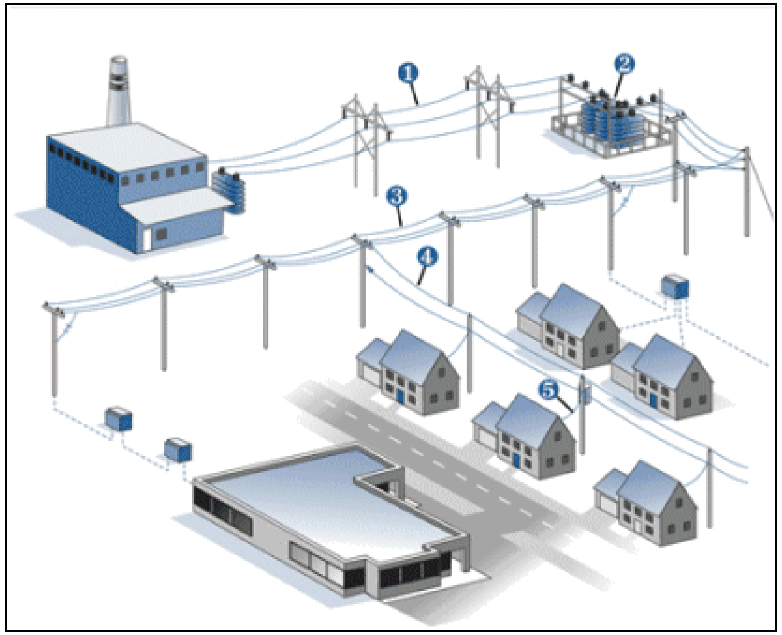
Feeders broken into three sections by switches

Each section carries 25% of feeder capacity

Closed switches

Open switch

Feeder is loaded to 75% of capacity at full loading to be capable of carrying section of adjacent feeder

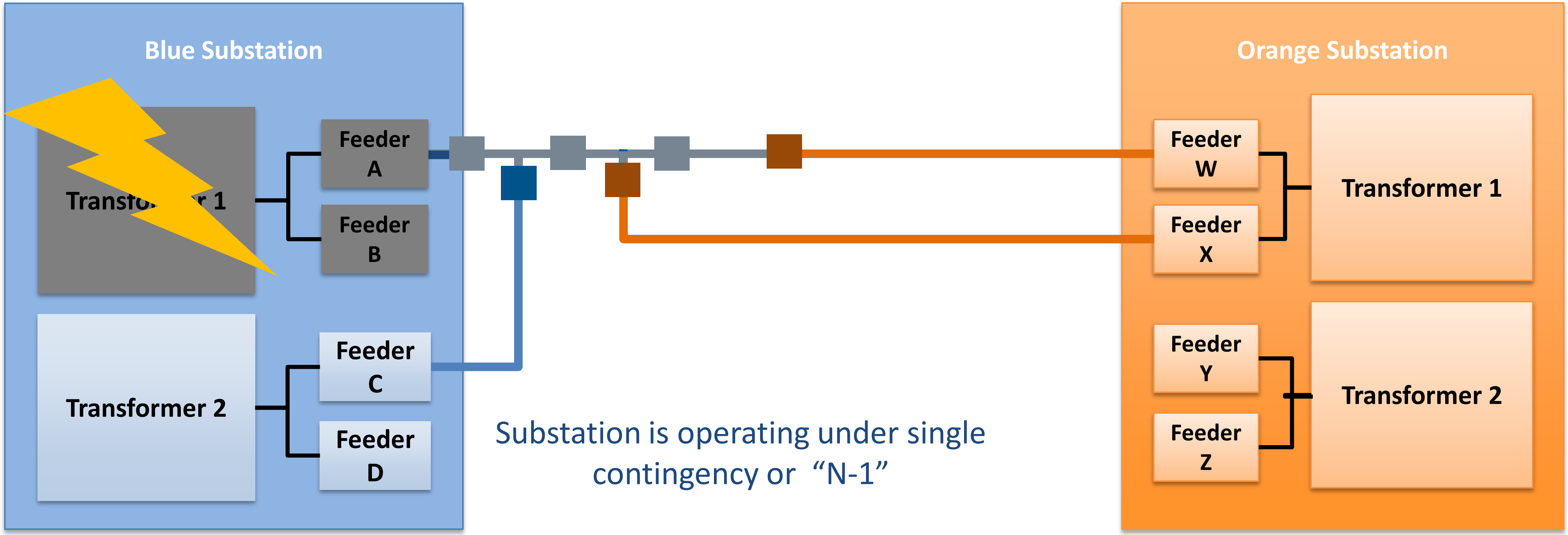


Credit: Ameren
https://www2.ameren.com/common/DistributionSystem.aspx

Contingency Capacity Criteria

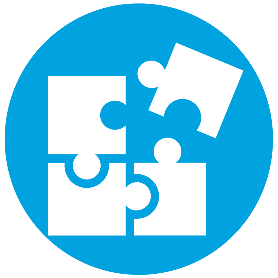
Safety Reliability

Example: Substation Transformer Outage



Substation is operating under single contingency or "N-1"

Distribution Planning Criteria – Capacity Constraints and EVs



Electric Capacity
- Normal
- Contingency

Voltage
Reliability

Source.Energy Systems Integration Group; data courtesy of Kevala, 2023; Public Advocates Office, 2023.

Transformer Replacement

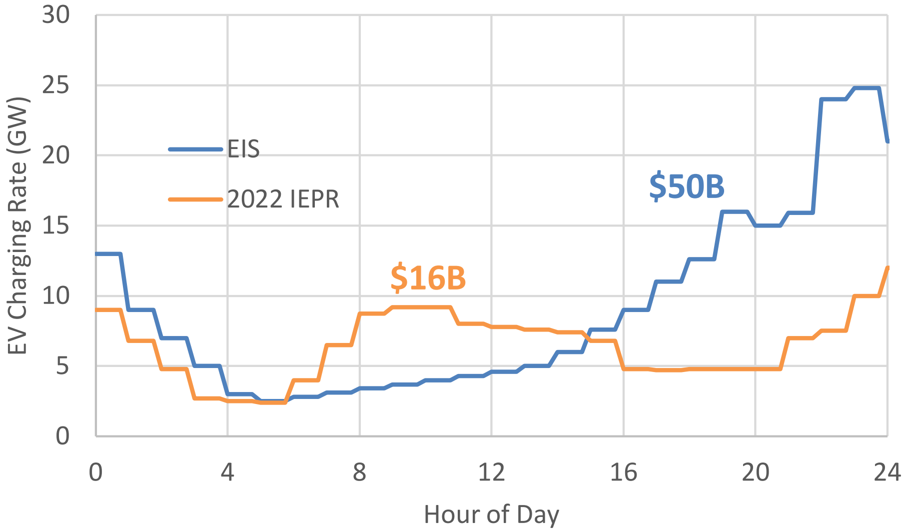
Exegol Utility District

When equipment is a candidate for replacement, the utility replaces legacy designs with similar design standards that may become overloaded with incremental EVs.

Tatooine Cooperative

When equipment is a candidate for replacement, either at end of life or when doing things like pole replacement, the utility replaces legacy designs with future-ready solutions.

Smart Charging



Differences in charging assumptions can have a large impact on the cost of distribution upgrades. Smart charging can adjust the charging profile.

Distribution Planning Criteria – Voltage Violations and PV

Safety

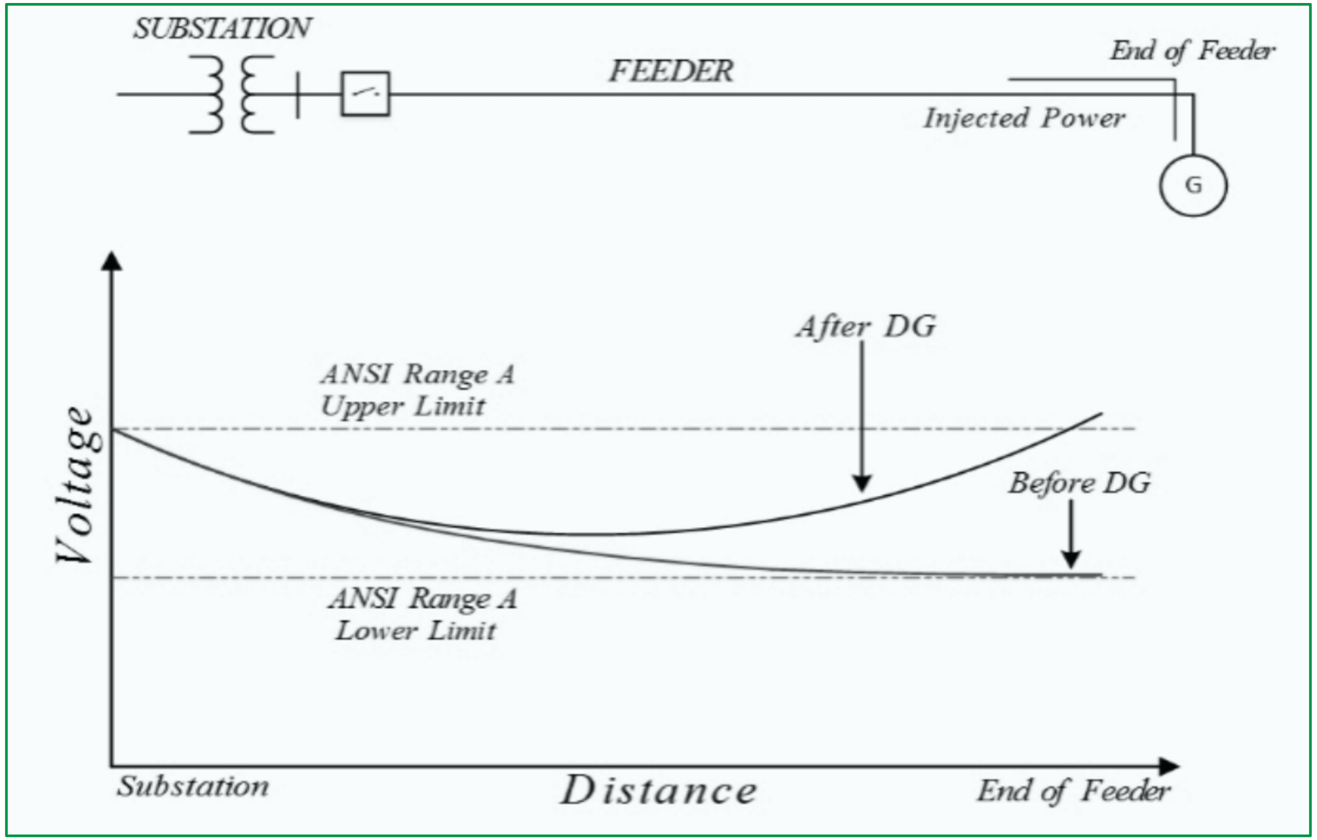
Reliability

Electric Capacity
- Normal
- Contingency

Voltage

Reliability

Illustration of Voltage Criteria



Sahito, Anwar & Memon, Zubair & Buriro, Ghulam & Memon, Sarwan & Jumani, Muhammad. (2016). Voltage Profile Improvement of Radial Feeder through Distributed Generation. SINDH UNIVERSITY RESEARCH JOURNAL (SCIENCE SERIES). 48. 497-500.

Q&A Break

Investment Categorization

Cost

- **Distribution investments are frequently lumped together in grid modernization proceedings, but for cost-effectiveness evaluation and cost allocation it's important to categorize investments according to type and drivers.**
- **In terms of type, a high-level taxonomy of investments might include:**
    - Existing infrastructure replacements and upgrades (e.g., 4 kV to 12 kV upgrades)
    - Line extension and service upgrades (e.g., new service requests, amperage upgrades)
    - Distribution capacity expansion (e.g., substation upgrades)
    - Hardening (e.g., undergrounding, steel/concrete poles, raising equipment)
    - Grid technology (e.g., grid management and monitoring hardware and software)
    - Administrative (e.g., meters and backend software, billing software)

Source: Kahrl (3rd Rail) and de Martini (Newport)

Capacity Planning

Process to plan for adequate system capacity under normal and contingency operations

Capacity Planning is typically an annual process to address load growth or movement of load around the system

System analyzed for normal and contingency conditions

Solutions identified and proposed to address constraints

Asset Health

Programs to plan the replacement of aging assets

Asset health programs contribute to system reliability and the customer experience

Different approaches to asset health

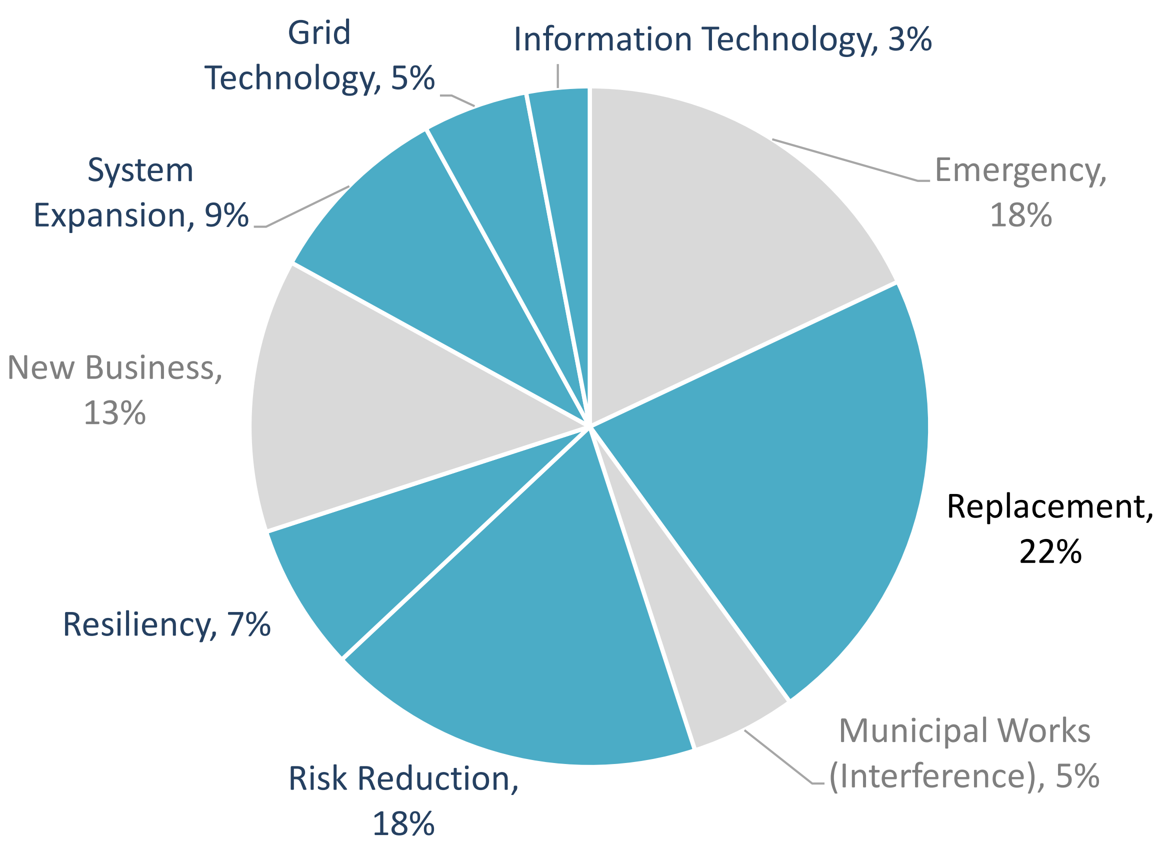
- Corrective Maintenance – replacing failed assets
- Preventative Maintenance – replacing assets prior to failure
- Reliability-Centered Maintenance – replace assets based on historic reliability records
- Condition-Based Predictive Maintenance – proactive and situational based

Utility Budgets: Discretionary vs Non-Discretionary

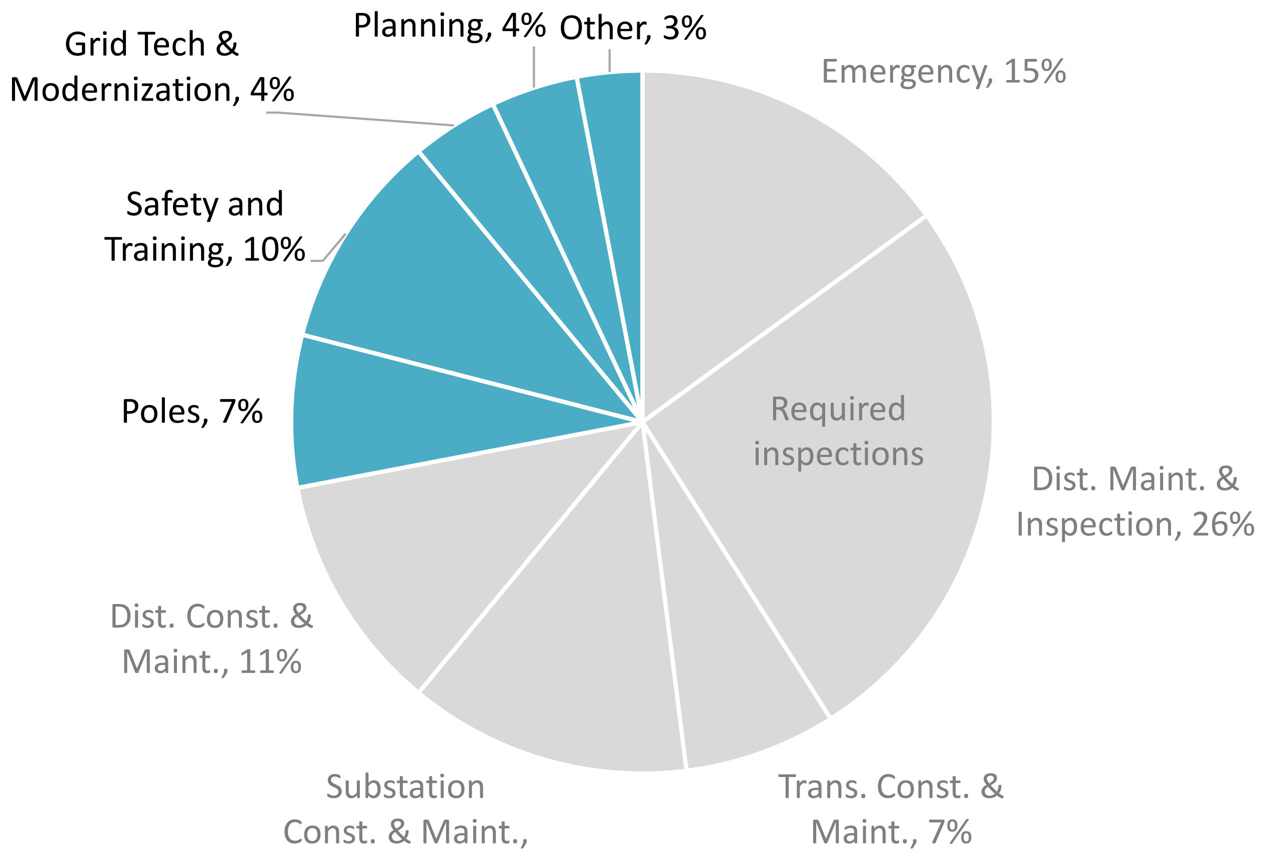
Cost

Utility capital and O&M expenditures can be deferrable or non-deferrable.

Capital



Operations and Maintenance



Development of Multi-Objective Distribution Plans

Integrated distribution planning should address the development of prioritized and optimized multi-year distribution plans.

Determine Grid Need

Assess grid health, resilience risks, customer load and DER growth needs

Identify Potential Solutions

Develop grid & non-wires solutions that address more than one objective

Evaluate C-E of Potential Solutions

Assess cost-effectiveness of grid & non-wires solutions

Develop Multi-year Plan

Prioritize & optimize expenditures with given financial and resource constraints

Planning Objectives

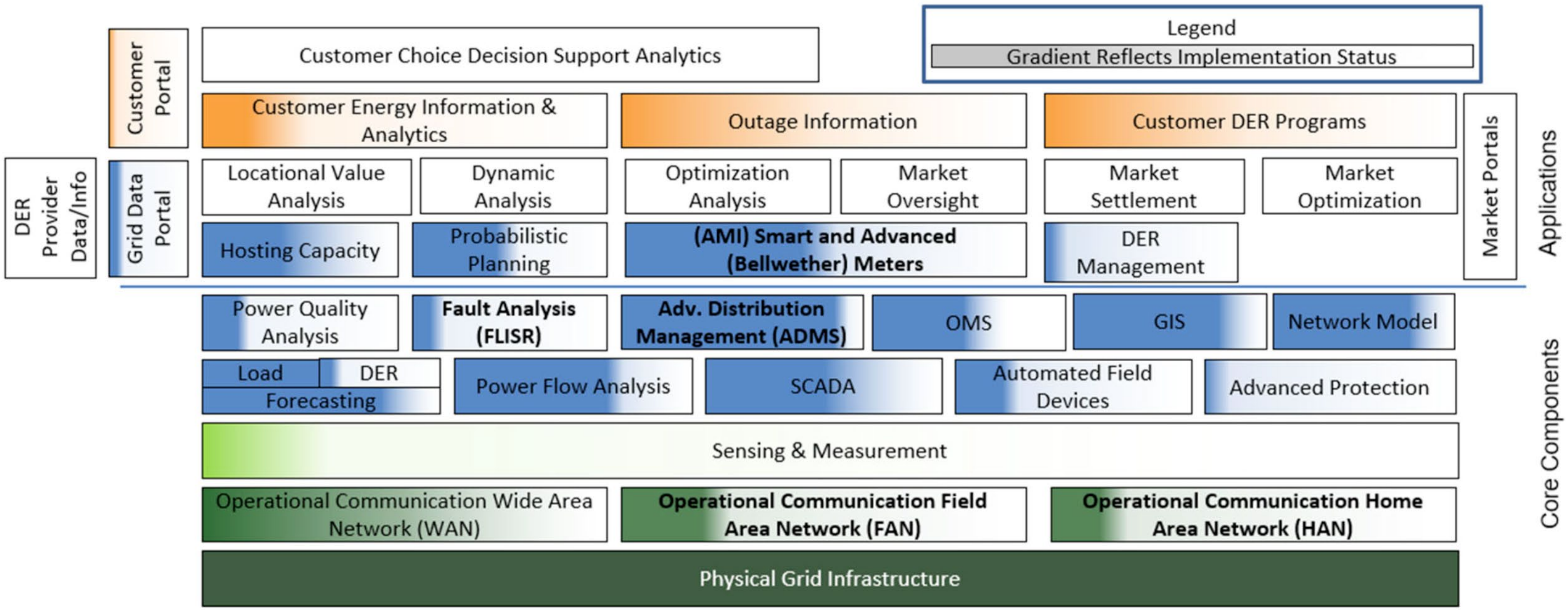
Improve Asset Health & Safety	Improve Reliability	Increase Capacity	Improve Resilience	Promote Equity
Address asset conditions that lead to failure	Reduce frequency & duration of outages	Expand capacity to address load growth & DER adoption	Address climate threat risks to critical grid infrastructure	Ensure benefits of the grid are fairly distributed

Source: Kahrl (3rd Rail) and de Martini (Newport)

State of the Grid and Gap Analysis

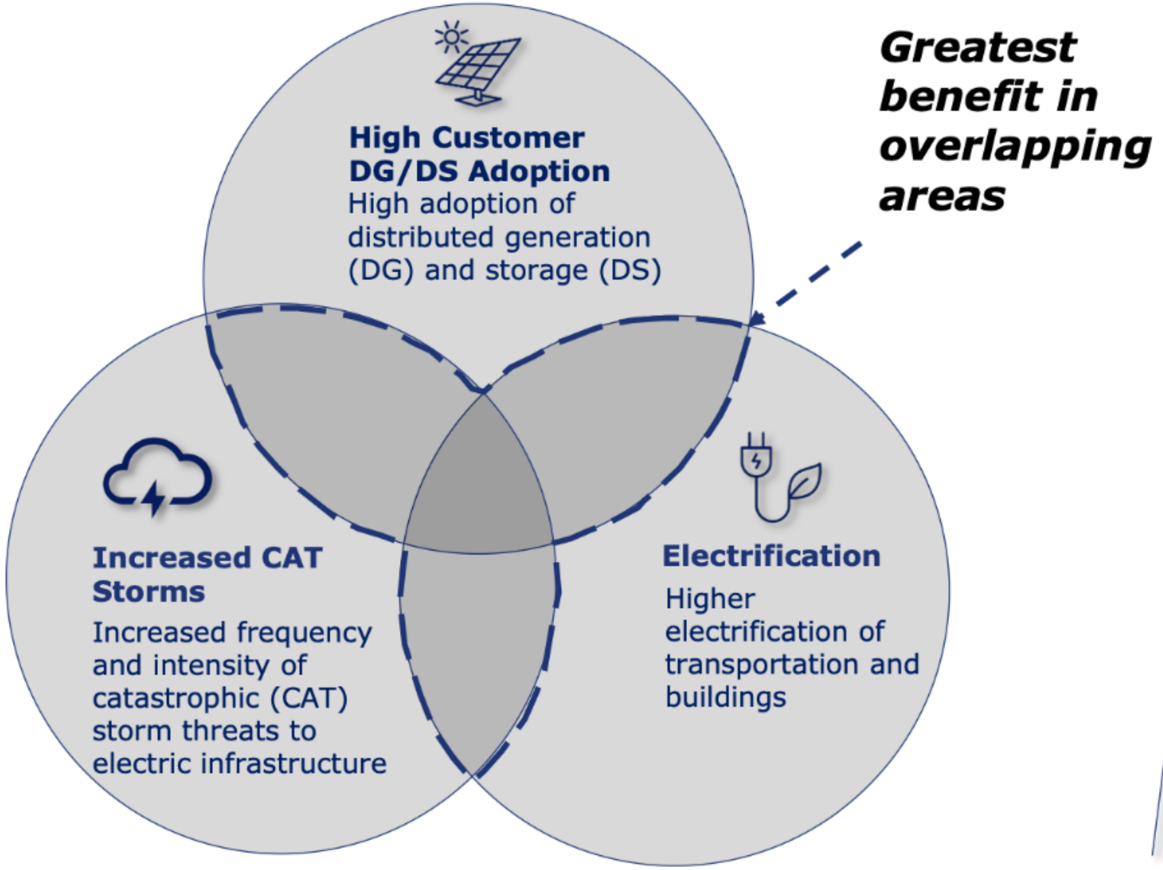
- **Determine the status of current tools and capabilities**
- **Track progress in each area and identify where investment is most needed**
- **Grid modernization status provides a gap analysis according to functionality and capability**
- **Next: Prioritize investments delivering joint and interdependent benefits according to objectives**

Xcel Grid Modernization Status (2023)



Source: Xcel Integrated Distribution Plan 2023

Scenario Analysis



- Three scenarios were developed to analyze the range of potential impacts to the grid if one or multiple scenarios materialize
- Scenarios are driven by unique sets of drivers that are expected to impact the grid over the next 15 years and beyond
- Each scenario includes three components to determine the potential investments needed for the grid:
  1. Plausible forecasts
  2. Grid impacts
  3. Signposts

While the Company invests in projects and programs that support individual scenarios, the **greatest benefit** is achieved by **identifying investment opportunities across multiple scenarios**

Source: DTE DGP 2023

Prioritizing Utility Investments

Goal: develop a list of **prioritized solutions** given **practical constraints**, such as budget limitations.

Steps:

1. Ranking planning objectives w/stakeholder input
2. Normalizing the value contribution of each solution in relation to one or more objectives
3. Developing a prioritized list

See example: DTE Electric Company's 2021 Distribution Grid Plan, pp. 82-90; https://mi-psc.force.com/sfc/servlet.shepherd/version/download/068t000000Uc0pkAAB.

Illustrative Value-Spend Efficiency Method

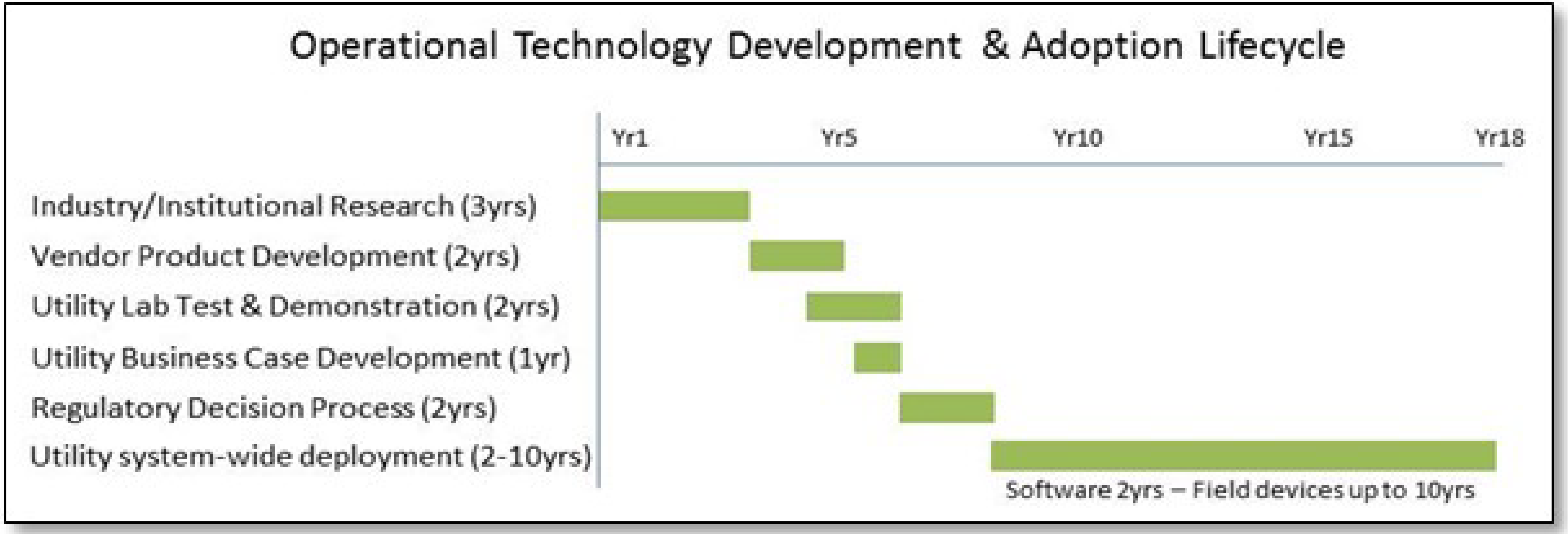
	Planning Objectives Ranked (1-5)									
Specific Projects	Safety (5)	Service Compliance (5)	Reliability (3)	Resilience (4)	Electrification (3)	DG/DS Integration (3)	Equity (4)	Score	Cost ($mm)	Spend Efficiency (S/C)
Tree Trimming[1]	5		3	3				11	$2.5	4.4
Undergrounding[2]	3		3	4	1	1	2	14	$5.0	2.8
Pole/Tower Hardening	2	2	3	4			1	15	$2.0	7.5
4kV Voltage Upgrade Conversions	4	4	2	3	3	3	3	22	$10.0	4.5
Substation Breaker Replacement[2]	5	5	3		1	1		15	$2.0	7.5
ADMS		3	3	3	2	3	1	15	$2.5	6.0
Field Automation[2,3]	3	3	3	3		1	2	15	$3.0	5.0
Advanced Metering	1	2	2	1	1	3	1	11	$2.5	4.4

1. Improved reliability & resilience supports greater consumer reliance on electrification
2. If program involves using larger conductor or higher capacity equipment
3. Improved reliability and resilience of grid improves the availability for DER to provide bulk power & grid services

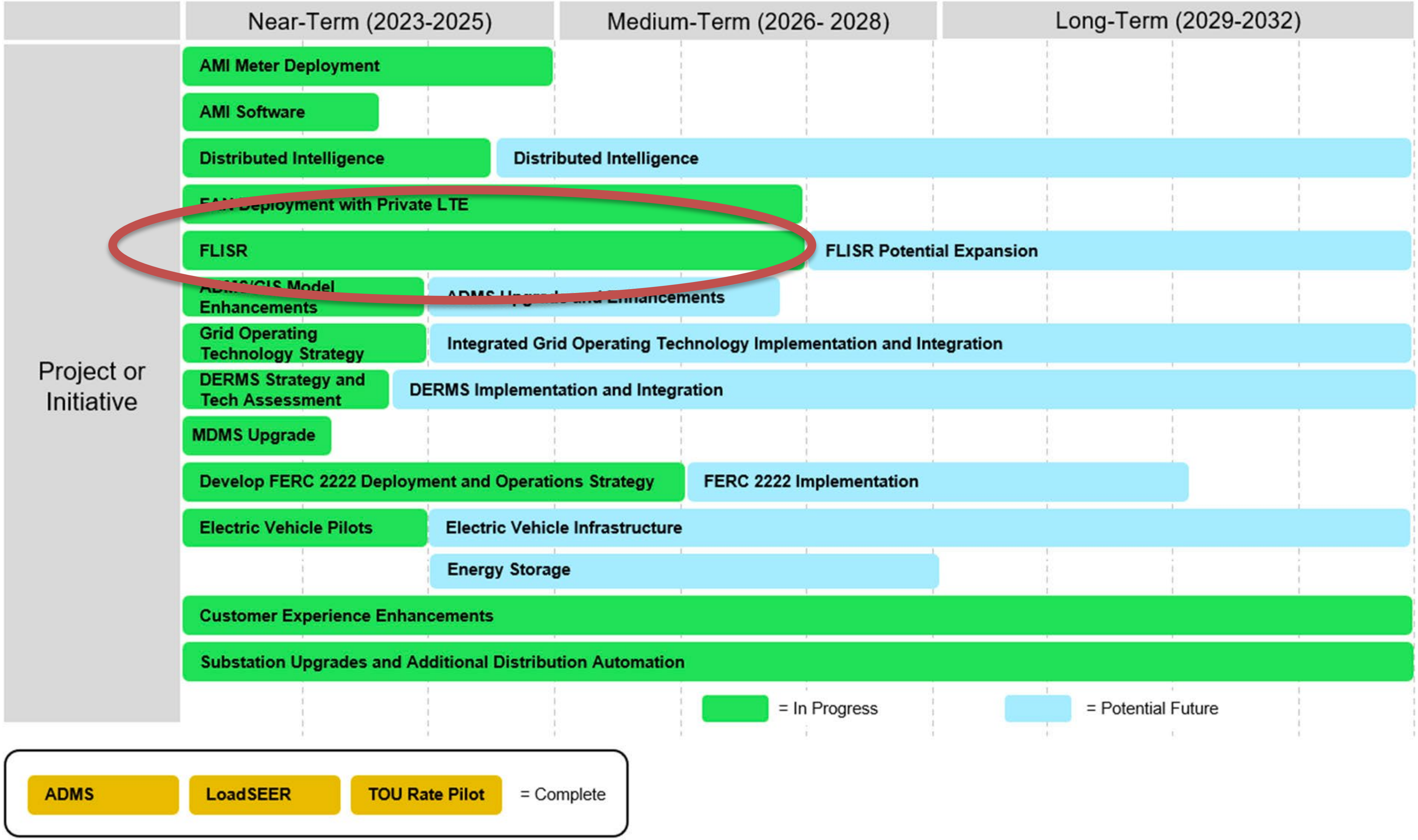
Source: Integrated Resilient Distribution Planning, by P. De Martini, J. Taft, A. De Martini, and M. Hall, PNNL-32883, May 2022. Available at: https://gridarchitecture.pnnl.gov/media/advanced/Integrated_Resilient_Distibution_Planning.pdf.

Technology Adoption Timing Considerations

Required efforts to develop, demonstrate, test, and deploy new technologies are incorporated into an IDSP grid modernization strategy



Example Technology Roadmap



Source: Xcel Energy (2023)

Mapping Technologies to Objectives: **Reliability**

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Source: *Modern Distribution Grid, Volume I: Customer and State Policy Driven Functionality, DOE, 2017;* Available online at: https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid_Volume-I_v1_1.pdf

Example: Fault Location Isolation and System Restoration (FLISR)

Benefits

- Improve reliability - Two-thirds reduction in the number of customers who experience a sustained outage because of a fault

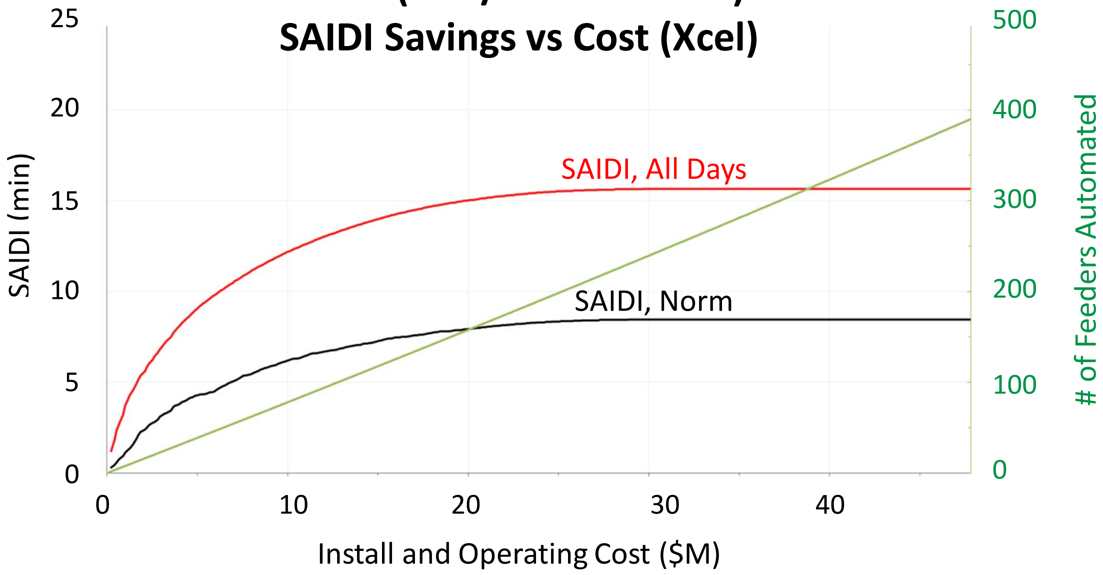
Phased Deployment

- Deployed on ~200 feeders over 5 years, focusing on lower reliability performance and/or circuits with existing field devices
- Phased functionality: Local mode, fault location prediction, open loop, closed loop

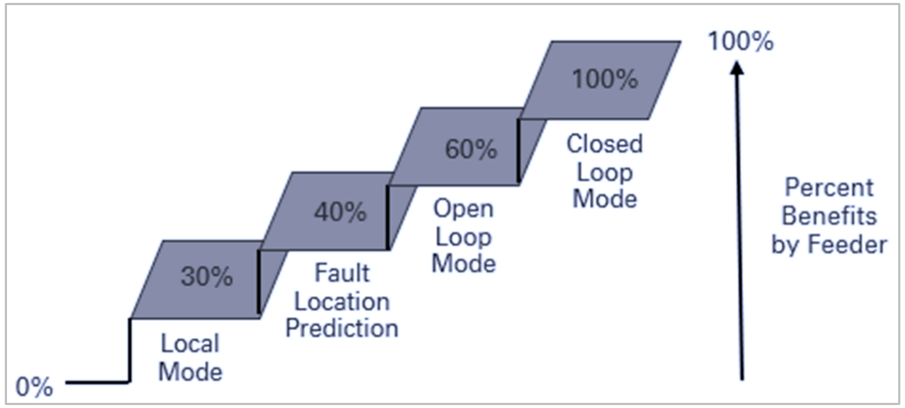
Challenges in quantifying benefits

- Sustained outage indices (SAIDI, SAIFI) might improve while performance of momentary outages (MAIFI) declines
- Customer average interruption duration index (CAIDI) performance might decline as shorter interruptions are mitigated

FLISR (cost/benefit value)
SAIDI Savings vs Cost (Xcel)



Phases of FLISR Functionality and Benefits (Xcel)



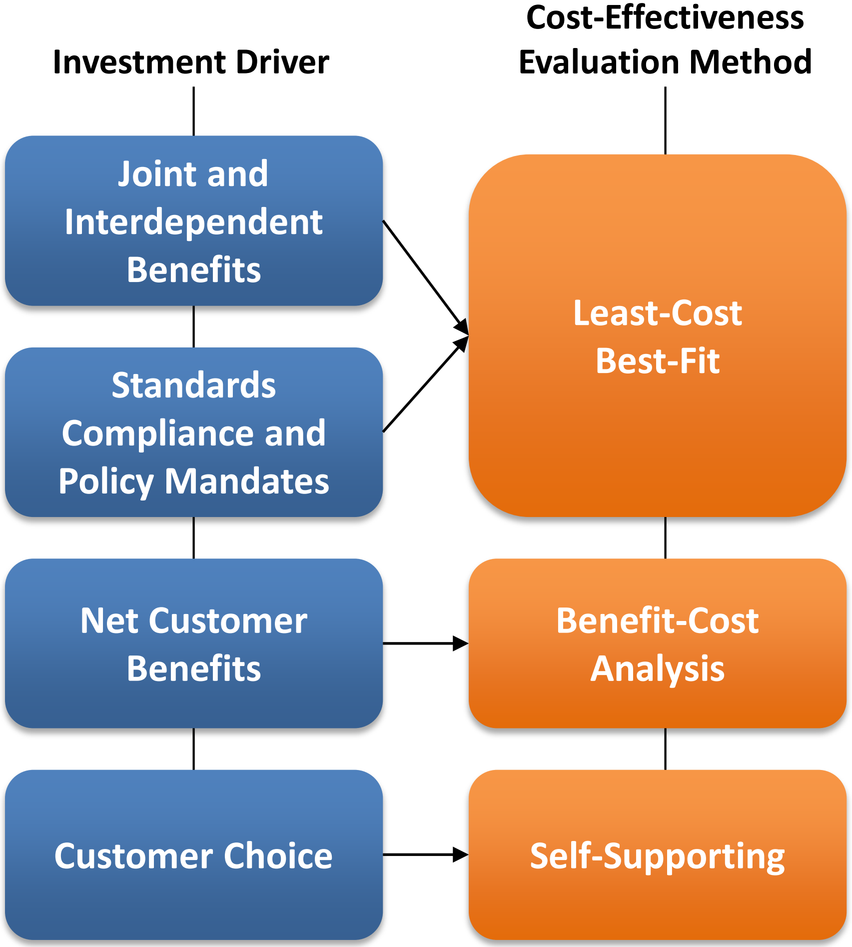
Source: Xcel Energy (2023), Xcel Energy (2023)

Investment Drivers and Cost-Effectiveness Evaluation Methods

Investments can be grouped under four key drivers:

1. **Joint and interdependent benefits** — core platform investments that are needed to enable new capabilities and functions in the distribution grid (e.g., distribution management systems)
2. **Standards compliance and policy mandates** — utility investments that are needed to comply with safety and reliability standards or to meet policy mandates for proactive investments to integrate DER (e.g., replacements and upgrades)
3. **Net customer benefits** — utility investments from which some or all customers receive net benefits in the form of bill savings (e.g., advanced metering infrastructure)
4. **Customer choice** — utility investments triggered by customer interconnection, opt-in utility programs, and customer-driven reliability improvements, paid for by individual customers (e.g., line extensions, hardening)

The investment driver points toward an appropriate cost-effectiveness evaluation method (right side of figure).



Source: Kahrl (3rd Rail) and de Martini (Newport)

Applying Economic Evaluation Methods

Least-cost best-fit (LCFB) and benefit-cost analysis (BCA) are used in different situations and answer different questions.

LCBF – used for most distribution infrastructure investments and platform software investments

- *Given that we want some functionality/capability on the distribution system or that we want to meet some safety, reliability, or regulatory goal, what is the lowest cost way to do so?*

BCA – used for investments in advanced meters (often but not always), non-wires alternatives, utility resource procurement and programs

- *Will an investment enhance welfare (benefits > costs) for all or a subset of customers?*

There may be an overlap between BCA and self-supporting investments, which historically have been addressed through cost-sharing mechanisms (e.g., free footage allowances for line extension).

Source: Kahrl (3rd Rail) and de Martini (Newport)

Example: Applying Cost-Effectiveness Methods

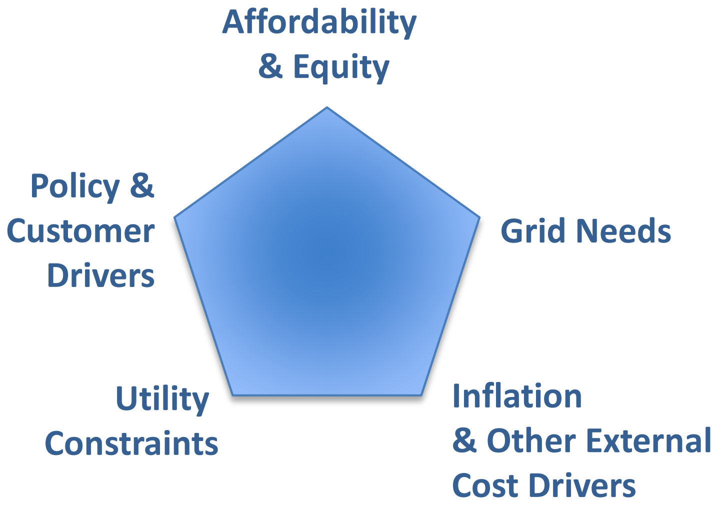
- **A state legislature develops a new statute requiring distribution utilities to meet minimum performance standards (e.g., outage frequency and duration, service restoration times) during extreme weather events.**
- **The PUC orders regulated utilities to review performance standards and approaches and propose spending to meet these standards. The order also requires utilities to integrate microgrids that several communities have proposed.**
- **Evaluation and cost allocation**
    - **LCBF**: The law deems major hardening investments (e.g., raising substations in flood zones) to be in the public interest and that taxpayers will pay for them, up to a specified dollar cap.
    - **LCBF**: Investments that exceed the cap and more minor investments that are needed to meet the standard are financed by the utility, included in the utility's rate base, and paid by the utility's customers, if the Commission determines the costs are prudently incurred.
    - **BCA**: Net of wholesale benefits, the utility finds that microgrids are not a least-cost approach to meeting the performance standard.
    - **Self-supporting**: The utilities file a tariff for microgrid exports based on avoided costs. The PUC approves the tariff. Microgrid customers pay for net microgrid costs (incremental costs minus tariff revenues) and the higher reliability that it provides.

Source: Kahrl (3rd Rail) and de Martini (Newport)

Distribution Expenditure Evaluation Challenge

Evaluate utility distribution expenditure plans within a holistic frame

- **Transformation of energy use from fossil fuel to clean electricity will place considerable demands on the electric grid.**
- **Distribution systems will require expenditures, both capital investments and operational expenses (e.g., software as a service and non-wires alternatives), to enable policies and meet customer needs.**
- **Nearly all grid expenditures result in incremental costs* and related rate impacts, as most are not offset by utility operational savings.**
- **External factors such as inflationary effects on equipment and labor costs create an additional challenge.**
- **This requires navigating several interrelated factors (see figure) that will ultimately shape a financially reasonable trajectory to address desired outcomes.**



* While non-wires alternatives may avoid capital costs, they typically require utility payments to DER aggregators or directly to participating customers. These payments are usually treated as operating expenses. Both traditional and non-wires solutions are incremental costs that impact retail rates, although capital investments impact rates differently than operating expenses.

Source: Kahrl (3rd Rail) and de Martini (Newport)

Project vs. Portfolio Cost-Effectiveness

Project cost-effectiveness is the first step to evaluate an overall distribution plan.

However evaluation of individual grid modernization projects is insufficient to determine whether an overall distribution expenditure plan is reasonable.

It is also necessary to consider whether the proposed portfolio of expenditures:

- Clearly addresses more than one identified statutory or regulatory objective
- Represents an integrated set of projects that are complementary
- Represents a set of projects that are part of a series of expenditures to address identified statutory or regulatory objectives
- Represents a prioritized set of expenditures given the urgency of grid needs that address identified statutory or regulatory objectives and utility financial and resource constraints
- Represents an optimized set of expenditures respecting customer affordability and equity considerations

Distribution expenditure plans require a multi-objective decision-making framework to evaluate these considerations.

The objective is to achieve the highest value per dollar expended – "value-spend efficiency"

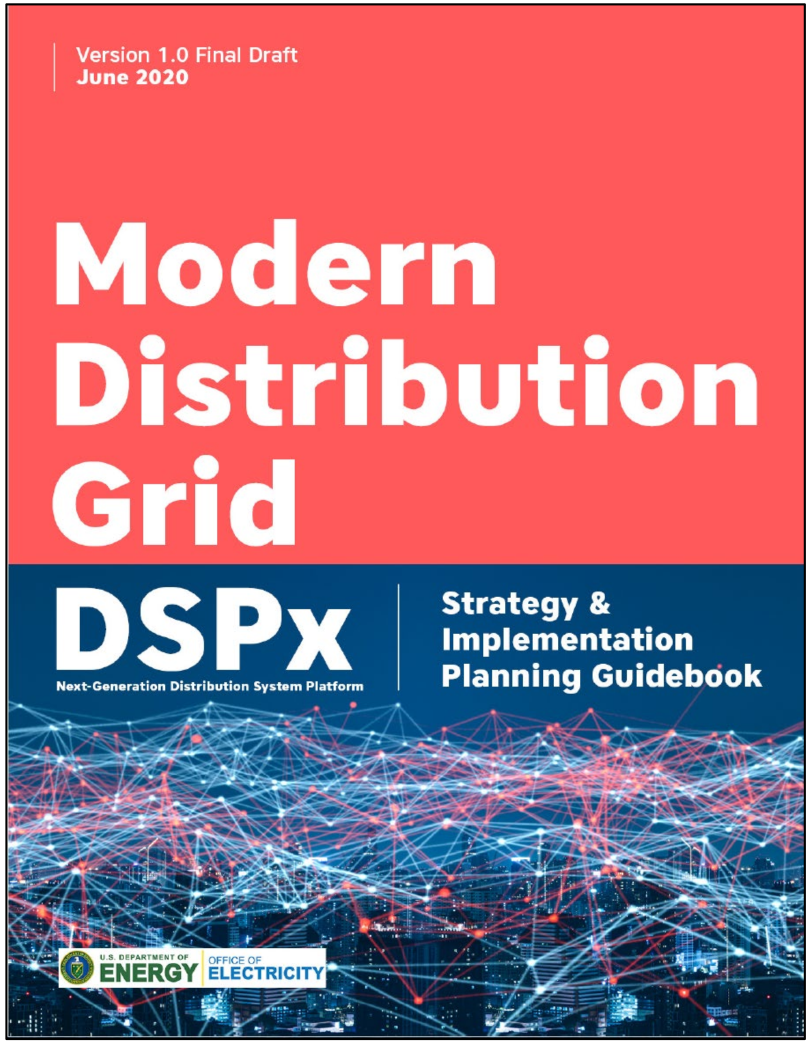
Source: Kahrl (3rd Rail) and de Martini (Newport)

DOE's Modern Distribution Grid Guidebook

Volume IV of the guide includes an economic evaluation framework for grid modernization investments.

- Aims to inform approaches to evaluating economics and managing costs and risks of grid modernization investments

No textbook approach — multiple reasonable paths to achieving the same broad goals



U.S. Department of Energy. *Modern Distribution Grid Volume IV: Guidebook*

Actions State Agencies Can Take

State agencies can help ensure planned utility investments meet state objectives and priorities. For example:

State regulators can provide guidance to utilities on:

- Translating state goals to standards for evaluating grid needs and investments
- Mapping investment priorities to state objectives and requirements
- Prioritizing investments that deliver multiple benefits according to objectives
- Quantifying benefits from grid modernization investments
- Expectations for cost-effectiveness evaluation — cost-benefit analysis vs. least-cost, best-fit approaches
- Considerations for proposed cost allocation

State Energy Offices* can:

- Develop state plans and conduct analysis to inform grid needs analysis and investment prioritization
- Facilitate or participate in stakeholder processes to discuss proposed investments
- Participate in regulatory proceedings, including contributing to frameworks that govern DSP

Utility consumer advocates can:

- Participate in stakeholder meetings convened by utilities, commissions, or State Energy Offices to review grid needs and investment options
- Review analysis of customer impacts, including costs and benefits, for rigor and comprehensiveness

*State Energy Offices' Engagement in Electric Distribution Planning to Meet State Policy Goals

Questions to Ask

Have clear objectives been established in policy or regulation, or proposed by the utility?

What are the appropriate planning objectives and criteria for your state's distribution systems?

What is the utility's grid modernization strategy and roadmap, and how will they meet state objectives?

What is the appropriate investment prioritization model recognizing multiple objectives and multiple benefits?

What level of oversight and transparency is required to facilitate stakeholder buy-in and ensure objectives are achieved?

How does the plan address uncertainty in the pace and scope of change — e.g., in technologies and policies — over the planning period, and how do the grid mod strategy and roadmap address the needs?

Contact

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